Dispersion Factors in DSM2-QUAL

- Introduction
- Classic dispersion
- Implementing dispersion in QUAL
- Estimating dispersion factor in QUAL
- Application of estimation

Introduction

- Dispersion factor determines mixing in QUAL
- Dispersion in DSM2 is not “classic” Fischer
- Goals:
  - Relate DSM2 mixing to classic dispersion
  - Find out if a DSM2 dispersion factor is limited physically by a value of 1.0 – NO!!!
  - Determine guidelines for reasonable values
  - Understand dependence on geometry and flow

- Introduction
- Classic dispersion

Classic Dispersion and QUAL

- Classic dispersion describes mixing due to eddy circulation and velocity differences over the channel cross section.
- Classic dispersion is modeled by a “diffusion analogy” – looks like diffusion equation.
- QUAL’s mixing formula describes volume exchanges between parcels over a time step.
- QUAL’s mixing is a finite-difference approximation to diffusion under steady conditions, similar under other conditions.

Basic Transport Equation

- With respect to a axis which moving in mean flow speed

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial \xi}\left(D \frac{\partial C}{\partial \xi}\right),$$

Dispersion coefficient

- D is a macro indicator of the diffusing ability of flow under study.
- D is a physical parameter with unit (L^2/T), whose values depends on flow profile and stream geometry

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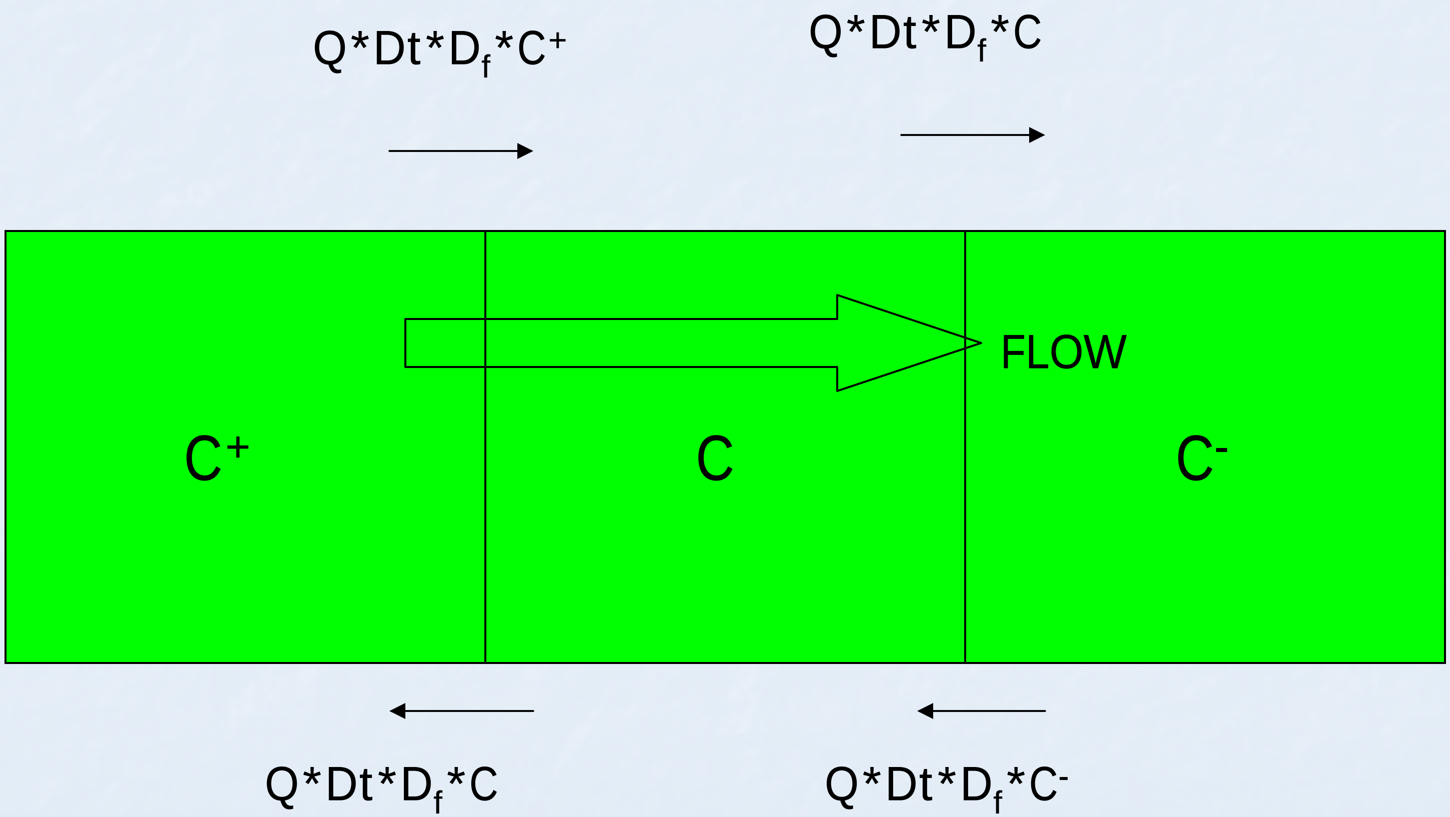
Mixing Mechanism in QUAL



DSM2-QUAL Dispersion

- QUAL is a finite diff. approximation to the diffusion equation under steady flow for this definition of D_f (BLTM user manual):

$$D_f = \frac{D}{|u|\Delta x},$$

Where:

u is cross-section mean flow velocity

Δx is length of water parcel used in approximation

- This definition on the previous slide answers the question:

  “What is physical interpretation of the QUAL dispersion factor”

For steady flow, D_f is ratio of dispersion to advection. The ratio is dimensionless.

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Fischer Dispersion

- Fischer gave a empirical formula to estimate dispersion coefficient *D* (not D_f) for streams:

$$D = \frac{0.011uW^2}{du^*}$$

- Empirical observations of estuaries:

$1000 < D\ (ft^2/s) < 12000$

*For estuaries D tends to be lower

Comparing DSM2 to Fischer: 2 methods

- Substitute Fischer's stream formula for D in QUAL's coefficient D_f:

$$D_f = \frac{0.011 |u| W^2}{du^* \Delta x}$$

- Compare Fischer's estuary observations to QUAL's coefficient:

$$D_f = \frac{D}{|u| \Delta x},$$

Wide Channel Example

- Channel 640 used in extension grid
- Parcel length Δx=2000 ft
- Width w=8000 ft
- Depth d=50 ft (typical)
- Slope estimate S=0.0008
- Mean flow velocity u=1.75 ft/s, shear velocity u*=1.135

Stream formula prediction:

$$D_f = \frac{0.011 * 1.75 * 8000^2}{50 * 1.135 * 2000} = 10.85.$$

Estuary Observation Prediction: $0.3 < D_f < 3.4$

Estuary Channel Example

- Channel 133 (middle river)
- Simulated discharge 1028 cfs
- Parcel length Δx=300ft
- Width w=240 ft
- Depth d=8.7 ft
- Slope estimate S=0.000204
- Mean flow velocity u=0.49 ft/s, shear velocity u*=0.24 ft/s

$$D_f = \frac{0.011 * 0.49 * 240^2}{8.7 * 0.24 * 300} = 0.5$$

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- A application of wide channel with large dispersion (10-12) factor as extension of DSM2 grid down to the Golden Gate has been done
- Extended DSM2 grid can repeat historical EC at Martinez point, and also simulated EC of same magnitude with 2D model (RMA) in island flooding simulation

Conclusions

- Dispersion factor D_f can be larger than 1.
  - Stream formula gives larger values than estuary observations
- Larger channels D_f can be greater than smaller channel by order of magnitude
- Implications:
  - Still examining SF Bay Extension Grid
  - Calibration should take this into account
  - Small Channels may have very small D_f